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Mulch type affects growth and tuber production of yellow nutsedge (*Cyperus esculentus*) and purple nutsedge (*Cyperus rotundus*)

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Polyethylene mulch is an effective component of weed management in vegetable production. However, nutsedges are persistent and proliferate in these systems. Greenhouse studies evaluated the growth and tuber production of purple nutsedge and yellow nutsedge grown in pots covered with black-opaque polyethylene mulch, clear-colorless polyethylene mulch, or nonmulched. Single, presprouted nutsedge tubers were planted and growth evaluated over 16 wk. Relative to the nonmulched, yellow nutsedge shoot production was reduced 46 and 72% by black and clear mulch, respectively. The number of yellow nutsedge shoots that pierced and emerged through black and clear mulches was reduced 96% relative to emerged shoots in the nonmulched control. Yellow nutsedge in the nonmulched produced 366 tubers per initial tuber, whereas tuber production was reduced 49 to 51% in black and clear mulch. Growth of purple nutsedge shoots and tubers in black polyethylene mulch was similar to the nonmulched. Clear polyethylene reduced purple nutsedge tuber biomass relative to nonmulched, but clear mulch was similar to black mulch in nearly all measured variables. Without mulch, yellow nutsedge produced more shoots, shoot biomass, tubers, tuber biomass, and root biomass than purple nutsedge. However, growth of yellow nutsedge was hindered by polyethylene mulch, whereas differences in purple nutsedge growth among mulches could not be detected. The relative insensitivity of purple nutsedge and sensitivity of yellow nutsedge growth to the physical mulch barrier could lead to a shift in nutsedge species composition in mulched vegetable production.

Nomenclature: Purple nutsedge, *Cyperus rotundus* L. CYPRO; yellow nutsedge, *Cyperus esculentus* L. CYPES.

Key words: Methyl bromide alternative, physical weed control, polyethylene mulch.

Methyl bromide has been the foundation for pest (e.g., soil-borne insects, plant pathogens, and weeds) management in vegetable crop production in the southeast United States. However, the use of methyl bromide as a preplant pest management tool is scheduled to be abolished in 2005. Beyond 2005, use of methyl bromide will only be allowed through critical use exemptions agreed to by the Montreal Protocol participants (U.S. EPA 2005). Significant research has been conducted in an effort to find suitable alternatives to methyl bromide. Many of the identified methyl bromide alternative systems are based on compounds that require high application rates for acceptable pest control (e.g., 1,3-dichloropropene, metam, methyl iodide, and chloropicrin) (Csinos et al. 2000; Haar et al. 2003; Hutchinson et al. 2004; Schneider et al. 2003; Zhang et al. 1997). A number of these fumigant alternatives may only be short-term replacements for methyl bromide because of potential regulatory issues (e.g., questions surrounding environmental concerns, pesticide reregistration process, and worker protection standards) (Ajwa et al. 2002).

In many vegetable crops, an effective long-term alternative to methyl bromide for nutsedge management has not been identified. Purple nutsedge and yellow nutsedge are the most troublesome weeds of vegetable crops in Alabama, Georgia, Mississippi, Tennessee, and Texas (Webster 2002; Webster and MacDonald 2001). Based solely on the lack of nutsedge control with methyl bromide alternatives, a critical-use exemption for methyl bromide was granted for several vegetable crops in Georgia beyond 2005 (A. S. Culpepper, personal communication). Successful nutsedge management in vegetables should begin with the design of crop production systems that minimize nutsedge impact on the crop (Cardina et al. 1999; Lewis et al. 1997). Polyethylene mulch is one component of vegetable production systems with the potential to alter nutsedge growth and fecundity (Chase et al. 1998, 1999; Patterson 1998; Webster 2005). A greater understanding of the ecology of nutsedges in plasticulture production systems may assist in the development of appropriate management strategies in vegetables.

Polyethylene mulch is commonly used in production of fruiting vegetables (e.g., eggplant [*Solanum melongena* L.], pepper [*Capsicum annum* L.], and tomato [*Lycopersicon esculentum* L.]) and cucurbits [e.g., cucumber (*Cucumis sativus* L.), muskmelon [*Cucumis melo* L.], squash [*Cucurbita pepo* L.], and watermelon [*Citrullus lanatis* (Thunb.) Mansf.]) in the southeast United States. Suppression of the establishment of many grass and broadleaf weeds is a significant benefit of polyethylene mulch (Patterson 1998). However, nutsedges can penetrate the mulch and successfully compete with crops (William 1976). Previous studies have documented that mulches can affect tuber production of yellow nutsedge and purple nutsedge (Patterson 1998), but no

Table 1. The effect of polyethylene mulch on the growth of a single nutsedge tuber and its progeny after 16 wk.

Species	Mulch	Shoot number[a]			Shoot biomass[a]		
		Above mulch	Below mulch	Total	Above mulch	Below mulch	Total
		Number pot^{-1}			g plant^{-1}		
Purple	Black	10	14	24	8.3	5.8	14.1
	Clear	3	12	15	2.9	7.1	10.0
	None	15	N/A	15	11.1	N/A	11.1
Yellow	Black	6	73	79	18.4	17.7	36.1
	Clear	2	39	41	5.1	10.2	15.3
	None	146	N/A	146	35.5	N/A	35.5
$LSD_{0.05}$		16	9	18	5.1	4.2	4.8

[a] Values include shoot from initial tuber.

study has simultaneously compared nutsedge tuber production of both species in response to polyethylene mulch. The hypothesis of this study was that mulch treatments would equally affect the growth of purple nutsedge and yellow nutsedge.

Materials and Methods

The objective of this study was to evaluate the effect of black-opaque and colorless-clear polyethylene mulches on growth and reproduction of single plants of purple and yellow nutsedge over 16 wk. Greenhouse studies were conducted in Tifton, GA, in the spring of 2001 and 2002. Experimental units consisted of circular pots of 59-cm-diam by 23-cm-depth. Pots of this depth were selected because previous research indicated that 99% of purple nutsedge tubers were distributed within 16 cm of the soil surface (Siriwardana and Nishimoto 1987). Pots were filled to the top with sifted, sterilized, Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) consisting of 86% sand, 7% clay, and 7% silt. Each pot was covered with either black polyethylene mulch (thickness of 32 μm), clear-colorless polyethylene mulch (thickness of 32 μm), or had no mulch. Mulches were stretched across the top of each pot, in direct contact with the soil, and secured in place using stretch cords. To establish the experimental units, a pre-sprouted nutsedge tuber with a single shoot was transplanted through a small hole that was made in the mulch, to a soil depth of 2.5 cm, in the middle of each pot. The study was arranged as a randomized complete block design with three replications and was repeated over time. Replications were blocked by initial nutsedge tuber biomass as previous research indicated a significant correlation between tuber biomass and subsequent shoot biomass (Stoller et al. 1972). Pots were equipped with a drip irrigation line to facilitate watering under the mulch and were watered as needed.

In both 2001 and 2002, the study was initiated on March 1 and terminated after 107 d on June 18. During the duration of the study, nutsedge shoots that emerged through the mulches were monitored daily and marked with date of emergence using a small plastic sheath that slid to the base of the shoot. At the conclusion of the study, wire mesh (7.8 holes cm^{-2}) stretched across a wooden frame was used as a sieve to separate the tubers from the soil. Mature tubers were considered those structures that were capable of sprouting and supporting new growth. In contrast, swollen white tissue (diam < 2 mm) at the root tips, which were easily desiccated and incapable of supporting new growth (personal observation), were termed pretubers. Data collected from each treatment included: tuber number and biomass, pretuber number, above-mulch shoot number and biomass, and below-mulch shoot number and biomass. Height of the initial nutsedge shoot was measured weekly. Data were analyzed using analysis of variance and treatment means separated using Fisher's Protected $LSD_{0.05}$ test. The relationship between plant shoot height and time after planting was fit to a sigmoidal regression model.

Results and Discussion

Shoot Production and Growth

Relative to the nontreated control, yellow nutsedge shoot production was significantly limited by physical barrier of the polyethylene mulches. Yellow nutsedge produced 146 shoots in the nonmulched control (Table 1). In the black and clear mulches, six and two yellow nutsedge shoots, respectively, pierced and emerged through these barriers (Table 1). Previous research in field studies found fewer yellow nutsedge shoots emerged through clear mulch than with black mulch (Majek and Neary 1991). In the current study, biomass of yellow nutsedge shoots that emerged through the black mulch was less than biomass of emerged shoots in the nonmulched control but greater than that in the clear mulch.

A significant portion of the emerged yellow nutsedge shoots were trapped under the black mulch (73 of 79 shoots, 92%) (Table 1). Chase et al. (1998) reported that when grown in darkness, < 15% of yellow nutsedge shoots were trapped beneath black polyethylene mulch. In contrast, 89% of yellow nutsedge shoots were trapped beneath black polyethylene mulch in a field study (Majek and Neary 1991). Differences in yellow nutsedge penetration of the black mulch among these studies may be because of different levels of photosynthetic active radiation that made its way to the soil surface through holes in the mulch (especially the hole through which the initial shoot was transplanted in the current study) and potential differences in tautness of the polyethylene mulch. Similar to black polyethylene mulch in the current study, most of the yellow nutsedge shoots were trapped beneath clear mulch (39 of 41 shoots, 95%) (Table 1). There was greater consistency across studies in terms of yellow nutsedge failure to penetrate clear mulch, with ≥ 91% of yellow nutsedge shoots trapped below clear mulch (Chase et al. 1998; Majek and Neary 1991).

The number and biomass of yellow nutsedge shoots that

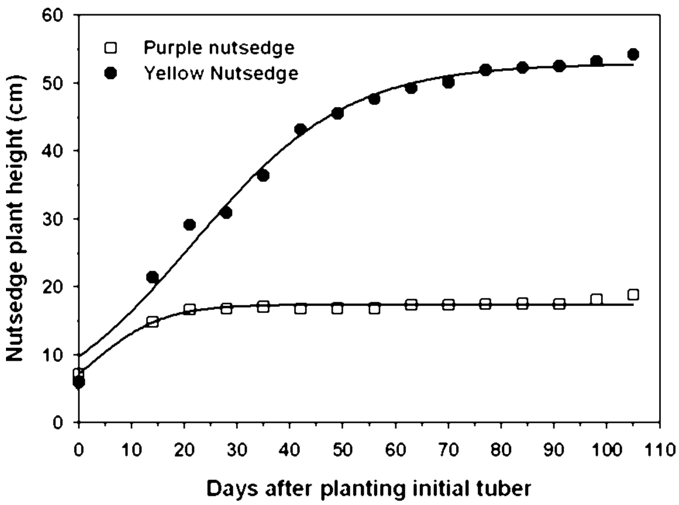

FIGURE 1. Height of purple nutsedge and yellow nutsedge plants. Data were combined by species across black mulch, clear mulch, and nonmulched control because of the lack of differences among mulch systems. Yellow nutsedge: $y = 53/(1 + \exp[-\{x - 21.6\}/14.6])$, $R^2 = 0.80$, P < 0.0001; purple nutsedge: $y = 17.4/(1 + \exp[-\{x - 2.3\}/6.7])$, $R^2 = 0.38$, P $<$ 0.0001.

failed to penetrate the black mulch and trapped beneath the mulch was 1.9-times greater than in the clear mulch treatment (Table 1). In spite of the greater yellow nutsedge shoot biomass trapped under black mulch relative to clear mulch, nearly all of the shoots under black mulch were brown and desiccated at the conclusion of the study (data not shown). Foliage that was in contact with the clear mulch became necrotic, but shoots with green tissue trapped beneath the clear mulch were plentiful. Previous research from New Jersey in cucumber found that black mulch had greater than twice as many shoots (density of 550 m^{-2}) trapped under black mulch than clear mulch. The total biomass (above and below the mulch) of yellow nutsedge shoots in the black mulch (36.1 g) was similar to the biomass of emerged shoots in the nonmulched control (35.5 g). However, the total biomass of yellow nutsedge shoots in clear mulch (15.3 g) was half that in the black mulch and nonmulched control.

Purple nutsedge produced 15 shoots in 107 d in the nonmulched control (Table 1). This is consistent with previously reported data that indicated 20 aerial purple nutsedge shoots produced from a single tuber in 90 d (Rao 1968). There were no detectable differences in the number of emerged purple nutsedge shoots among the mulch treatments. Previous research indicated that opaque mulch reduced purple nutsedge emergence through the mulch by 36 to 98% relative to the nonmulched control (Chase et al. 1999; Patterson 1998). However, in both of these studies, the mulch was laid over soil without nutsedge shoots protruding through the mulch. This is in contrast to the current study, where the initial shoot was planted through the mulch to evaluate the growth of a single nutsedge plant. However, only 39% (9 of 23 total shoots) of the subsequently developed purple nutsedge shoots that emerged pierced the black mulch (Table 1), consistent with previous research. Purple nutsedge shoots growing above clear mulch had less biomass than the nonmulched control. A similar number of purple nutsedge shoots and biomass grew below both black and clear mulches.

In the absence of mulch, yellow nutsedge produced nearly 10 times the number of shoots (146 yellow nutsedge shoots, 10 purple nutsedge shoots) and three times the shoot biomass (35 g of yellow nutsedge, 11.1 g of purple nutsedge) of purple nutsedge (Table 1). Although a similar number of yellow nutsedge and purple nutsedge shoots emerged through black and clear mulches, a greater number yellow nutsedge shoots failed to penetrate the black and clear mulches compared with purple nutsedge. Previous studies have shown that a greater percentage of purple nutsedge shoots were capable of penetrating clear mulch than yellow nutsedge under many different light levels (Chase et al. 1998).

Shoots of yellow nutsedge grew taller than purple nutsedge (Figure 1). Mulch did not have an effect on growth of the initial nutsedge shoot; therefore, data were combined over mulch type and analyzed by nutsedge species. The initial shoot of both species had a linear increase in height for the first 14 days after planting (DAP). However, whereas yellow nutsedge continued to have a near linear increase in growth for the first 42 DAP, growth of the initial purple nutsedge shoot leveled off at 21 DAP and did not exceed 19 cm. Yellow nutsedge shoot height was 53 cm at the conclusion of the study, more than twice the height of purple nutsedge.

Tuber Production

After 16 wk, a single yellow nutsedge tuber produced 365 new tubers in the nonmulched control (Table 2). Yellow nutsedge tuber production was similar to that in a field study in Minnesota (332 tubers produced in 16 wk) (Tumbleson and Kommedahl 1961), but lower than observed in Griffin, GA (622 tubers in 17 wk) (Hauser 1968). Produc-

TABLE 2. The effect of polyethylene mulch on the growth of a single nutsedge tuber and its progeny after 16 wk.

Species	Mulch	Tuber population[a]	Pretuber population	Tuber biomass[a]	Root biomass	Total subterranean biomass
		Number $plant^{-1}$		g $plant^{-1}$		
Purple	Black	47	199	16.5	9.3	25.8
	Clear	23	35	5.9	4.1	10.0
	None	66	312	23.9	12.2	36.1
Yellow	Black	179	62	20.4	17.9	38.3
	Clear	188	50	17.7	12.8	30.5
	None	366	120	59.5	24.0	83.5
$LSD_{0.05}$		71	65	13.0	7.8	14.8

[a] Values include initial tuber.

tion of yellow nutsedge tubers was hindered by polyethylene mulch. Both clear mulch and black mulch reduced yellow nutsedge tuber production to nearly half of the nonmulched control (Table 2). Previous research determined that yellow nutsedge tuber populations were reduced 79% by clear mulch relative to the nonmulched control. In the current study, the number of yellow nutsedge pretubers mirrored the trends observed with mature tubers (Table 2). There were approximately three mature yellow nutsedge tubers for each pretuber in all treatments.

In the nonmulched control, 66 purple nutsedge tubers were produced in 107 d. Previous studies from around the world reported a single purple nutsedge tuber producing 9 tubers in 51 d, 18 tubers in 60 d, 42 to 99 tubers in 90 d, 146 tubers in 3.5 mo, and 303 tubers in 4.5 mo (Hammerton 1974; Horowitz 1965; Mercado 1979; Rao 1968; Smith and Fick 1937). Previous research in Georgia has indicated that the timing of initial purple nutsedge tuber production in the field was correlated with the timing of early flowering, occurring 6 to 8 wk after foliar emergence (Hauser 1962). In the current study, flowering of purple nutsedge began 5 to 6 wk after transplant (data not shown).

The numbers of purple nutsedge tubers produced were similar among the mulch treatments and the nonmulched control (Table 2). Previous research demonstrated that purple nutsedge tuber populations were reduced 40% relative to the nonmulched control after 10 wk of growth with black-opaque mulch (Patterson 1998). In the current study, clear mulch (5.9 g) had less purple nutsedge tuber biomass than the nonmulched control (23.9 g), although neither was different from the tuber biomass in black mulch (16.5 g). It appears that purple nutsedge plants were commencing a significant growth expansion as the study concluded. There were 312 pretubers in the nonmulched control, 4.7 pretubers per mature purple nutsedge tuber (Table 2). The numbers of purple nutsedge pretubers were affected by mulch. There were fewer purple nutsedge pretubers in the black mulch (199 pretubers) than in the nonmulched control and fewer pretubers in the clear mulch (35 pretubers) compared with the black mulch.

Purple nutsedge produced 74 to 88% fewer tubers than yellow nutsedge in each treatment (Table 1). Average biomass per tuber in the nonmulched control indicated that purple nutsedge tubers (0.36 g tuber^{-1}) were approximately twice the mass of yellow nutsedge tubers (0.16 g tuber^{-1}). However, because of the high number of tubers, the sum of yellow nutsedge tuber biomass in the nonmulched control (59.5 g plant^{-1}) was more than double that of purple nutsedge (23.9 g plant^{-1}). There were no differences in tuber biomass between species within a mulch treatment, illustrating the greater growth suppression of yellow nutsedge due to mulch.

In summary, results suggest that polyethylene mulches may suppress growth of yellow nutsedge more than purple nutsedge. Both black and clear mulches reduced yellow nutsedge tuber production 49% and shoot populations $\geq$ 96% relative to the nonmulched control. In contrast, there were few detectable differences in purple nutsedge growth between the nonmulched control and black or clear mulches. The relative insensitivity of purple nutsedge compared with yellow nutsedge to the physical mulch barrier could lead to a shift in nutsedge species composition in mulched vegetable production. In the absence of the mulch barrier, yellow nutsedge produced 5.5 times more tubers, 2.5 times more tuber biomass, 9.7 times more shoots, and 3.2 times more shoot biomass than purple nutsedge. Although yellow nutsedge is more aggressive in growth than purple nutsedge, in mulched systems purple nutsedge may become the dominant weedy nutsedge. Previous research has determined that thinner mulches (30 to 64 μm) were more susceptible to puncture by purple nutsedge shoots than thicker mulches (100 to 254 μm) (Chase et al. 1999; Henson and Little 1969). Future efforts that further investigate mulch thickness or light transmission characteristics may contribute to purple nutsedge management in vegetable crop systems.

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Literature Cited

Ajwa, H. A., T. Trout, J. Mueller, S. Wilhelm, S. D. Nelson, R. Soppe, and D. Shatley. 2002. Application of alternative fumigants through drip irrigation systems. Phytopathology 92:1349–1355.

Cardina, J., T. M. Webster, C. P. Herms, and E. E. Regnier. 1999. Development of weed IPM: levels of integration for weed management. Pages 239–267 *in* D. D. Buhler, ed. Expanding the Context of Weed Management. New York: Haworth.

Chase, C. A., T. R. Sinclair, and S. J. Locascio. 1999. Effects of soil temperature and tuber depth on *Cyperus* spp. control. Weed Sci. 47:467–472.

Chase, C. A., T. R. Sinclair, D. G. Shilling, J. P. Gilreath, and S. J. Locascio. 1998. Light effects on rhizome morphogenesis in nutsedges (*Cyperus* spp): implications for control by soil solarization. Weed Sci. 46:575–580.

Csinos, A. S., D. R. Sumner, W. C. Johnson, A. W. Johnson, R. M. McPherson, and C. C. Dowler. 2000. Methyl bromide alternatives in tobacco, tomato and pepper transplant production. Crop Prot. 19:39–49.

Haar, M. J., S. A. Fennimore, H. A. Ajwa, and C. Q. Winterbottom. 2003. Chloropicrin effect on weed seed viability. Crop Prot. 22:109–115.

Hammerton, J. L. 1974. Experiments with *Cyperus rotundus* L., I: growth and development and effects of 2,4-D and paraquat. Weed Res. 14:365–369.

Hauser, E. W. 1962. Development of purple nutsedge under field conditions. Weeds 10:315–321.

Hauser, E. W. 1968. Yellow nutsedge—problems, research trends, and outlook. Proc. Northeast. Weed Cont. Conf. 22:37–48.

Henson, I. E., and E.C.S. Little. 1969. Penetration of polyethylene film by the shoots of *Cyperus rotundus*. PANS 15:64–66.

Horowitz, M. 1965. Data on the biology and chemical control of the nutsedge (*Cyperus rotundus*) in Israel. PANS 11:389–416.

Hutchinson, C. M., M. E. McGiffen, J. J. Sims, and J. O. Becker. 2004. Fumigant combinations for *Cyperus esculentus* L. control. Pest Manag. Sci. 60:369–374.

Lewis, W. J., J. C. vanLenteren, S. C. Phatak, and J. H. Tumlinson. 1997. A total system approach to sustainable pest management. Proc. Nat. Acad. Sci. U.S.A. 94:12,243–12,248.

Majek, B. A., and P. E. Neary. 1991. Selective wavelength transmitting mulch for yellow nutsedge control. Proc. Brighton Crop Prot. Conf. 1:263–268.

Mercado, B. L. 1979. Monogr. on *Cyperus rotundus* L. Biotrop. Bull. 15:1–63.

Patterson, D. T. 1998. Suppression of purple nutsedge (*Cyperus rotundus*) with polyethylene film mulch. Weed Technol. 12:275–280.

Rao, J. S. 1968. Studies on the development of tubers in nutgrass and their starch content at different depths of soil. Madras Ag. J. 55:18–23.

Schneider, S. M., E. N. Rosskopf, J. G. Leesch, D. O. Chellemi, C. T.

Bull, and M. Mazzola. 2003. U.S. Department of Agriculture—Agricultural Research Service research on alternatives to methyl bromide: preplant and post-harvest. Pest Management Science 59:814–826.
Siriwardana, G. and R. K. Nishimoto. 1987. Propagules of purple nutsedge (*Cyperus rotundus*) in soil. Weed Technol. 1:217–220.
Smith, E. V., and G. L. Fick. 1937. Nutgrass eradication studies, I: relation of the life history of nutgrass, *Cyperus rotundus* L., to possible methods of control. Agron. J. 29:1007–1013.
Stoller, E. W., V. M. Bhan, and D. P. Nema. 1972. Yellow nutsedge tuber germination and seedling development. Weed Sci. 20:93–97.
Tumbleson, M. E. and T. Kommedahl. 1961. Reproductive potential of *Cyperus esculentus* by tubers. Weeds 9:646–653.
[U.S. EPA] U.S. Environmental Protection Agency. 2005. United States nomination for methyl bromide critical use exemptions from the 2007 phaseout of methyl bromide. www.epa.gov/ozone/mbr/2007_nomination.html.
Webster, T. M. 2002. Weed survey—southern states: vegetable, fruit and nut crops subsection. Proc. South. Weed Sci. Soc. 55:237–258.
Webster, T. M. 2005. Patch expansion of purple nutsedge (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) with and without polyethylene mulch. Weed Sci. 53:839–845.
Webster, T. M. and G. E. MacDonald. 2001. A survey of weeds in various crops in Georgia. Weed Technol. 15:771–790.
William, R. D. 1976. Purple nutsedge—tropical scourge. Hortscience 11: 357–364.
Zhang, W. M., M. E. McGiffen, J. O. Becker, H. D. Ohr, J. J. Sims, and R. L. Kallenbach. 1997. Dose response of weeds to methyl iodide and methyl bromide. Weed Res. 37:181–189.

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